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NUTRITIONAL QUALITY ASSESSMENT OF TEN MULBERRY (MORUS) GERMPLASM VARIETIES THROUGH MOULTING TEST, SILKWORM REARING TECHNIQUE AND ECONOMICAL CHARACTERS OF BIVOLTINE SILKWORMS (*BOMBYX MORI* L) FOR COMMERCIAL EXPLOITATION

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Abstract: *Ten mulberry varieties viz., Tr_8, Tr_{12}, Tr_{20}, S_{1708}, MS_5, Matigara black, C_6, C_{10}, Morus nigra and M_5 were evaluated for leaf quality through rearing experiments using bivoltine (NB_4D_2) silkworms at Bethamangala, Kolar district. Results revealed that, silkworm larvae reared on S_{1708} leaves during II moult recorded highest larval weight (25.05mg) and moulting ratio (83.26%) and lowest larval weight (15.94mg) and moulting ratio (70.04%) recorded in silkworms reared on Morus nigra leaves. Silkworms reared on S_{1708} leaves recorded highest ten larval weight (43.21), cocoon weight (2.15g), shell weight (0.64g), shell percentage (20.96%), filament length (1142.69mts), renditta (5.07), denier (2.08) and E.R.R (79.98%) whereas lower ten larval weight (34.24g), cocoon weight (1.40g), shell weight (0.23g), shell percentage (15.12%), filament length (726.24mts), renditta (7.32), denier (2.98) and E.R.R (63.76%) were observed in Morus nigra mulberry variety. It is observed that, mulberry variety S_{1708} is superior in silkworm moulting and rearing tests compared to other varieties studied.*

Keywords: Evaluation, mulberry, *Bombyx mori*, feeding, moulting, rearing, cocoon characters.

INTRODUCTION

Silkworm (*Bombyx mori* L.) is essentially monophagous insect feeds solely on mulberry leaves (*morus* spp.). Its growth and development as well as cocoon and silk production entirely depends upon the quantity and quality of mulberry leaves (Nagaraju, 2002). Leaf quality is an important parameter used for evaluation of varieties aimed at selection of superior varieties for rearing performance (Bongale *et al*., 1997). It is well-established fact that, in sericulture, more than 60% of the total cost of cocoon production goes towards mulberry production alone. Hence, in recent years maximum attention has been given for the improvement of mulberry in terms of both quality and quantity. About 92.20% of silk produced in the world is obtained from mulberry silkworm *Bombyx mori* L. reared solely on mulberry leaves (*Morus* spp.). Growth and development of silkworm *Bombyx mori* L. and cocoon crop yield are mainly influenced by yield and nutritional quality of mulberry leaf used as feed (Yokoyama, 1963; Bongale and Chaluvachari, 1995). Superiority of different mulberry

varieties used as food for silkworm larvae greatly affects the economy of sericulture industry (Das and Sikdar, 1970). Nutritive value of mulberry (*Morus* spp.) leaf is a key factor besides environment and technology adoption for better growth and development of the silkworm larvae and cocoon production (Purohit and Pavankumar, 1996; Seidavi *et al*., 2005). Matsumara (1951) and Bose (1989) reported that, among the various factors influencing silkworm growth and cocoon production, leaf quality plays a major role. It is a confirmed fact that, leaf quality differs among mulberry varieties which in turn responsible for the difference in silkworm rearing performances (Aruga, 1994; Bongale *et al*., 1997). Leaves of superior quality enhance the chances of good cocoon crop (Ravikumar, 1988). In the present study an attempt has been made to evaluate better performing mulberry variety through silkworm rearing experiment for Kolar district is one of the premier and traditional sericulture belt of Karnataka, accounts for 40% of the total raw silk produced in Karnataka state.

MATERIALS AND METHODS

In the present study mulberry varieties like Tr_8, Tr_{12}, Tr_{20}, S_{1708}, MS_5, *Matigara black*, C_6, C_{10}, *Morus nigra* and M_5 were used. M_5 mulberry variety is used as a check variety for the comparison purpose. Cuttings of these varieties were procured from Central Sericultural Germplasm Resources Centre (CSGRC), Hosur-635109, Tamil Nadu, India and disease free bivoltine (NB_4D_2) egg layings obtained from National Silkworm Seed Project (NSSP), Bangalore, Karnataka were used. Mulberry plants were grown in field at Bethamangala village of Bangarapet taluk in Kolar district of Karnataka state (Fig.1). Experiment was conducted in RBD method with 4 replications / variety. Two years old plants were used for silkworm rearing from time to time in different seasons viz., summer, rainy and winter and the average values were tabulated in tables.

Silkworm Moulting.

Moulting test was carried out up to 2nd moult following standard rearing methods (Chaluvachari and Bongale, 1996) with four replications/variety and 100 larvae/replication. Tender leaves (1^{st}-4^{th} order) on healthy shoots were harvested and fed to young age silkworm larvae up to second moult (Benchamin and Nagaraj, 1987). Silkworm rearing was conducted under standard conditions (Krishnaswami, 1986b; 1990). Daily three feedings were given at 7am, 2pm and 10pm from brushing to end of II moult. First appearance of one larva out of moult was considered as commencement of moulting (Benchamin and Anantharaman, 1990). Comparative moulting ratio with respect of all the varieties leaves under evaluation was fixed depending on time duration which recorded more than 50% of the larvae under moult. Larval weight was also recorded.

Silkworm Rearing.

Silkworm rearing was conducted to test the efficiency of mulberry varieties selected (Fig.2). Rearing experiments were conducted at different seasons (rainy: July-August, winter: Nov-Dec, summer: March-April). For each mulberry variety, one egg laying was reared and four replications were maintained. After III moult, about 100 larvae / replication were maintained. Appropriate cellular rearing techniques were adopted and separate rearing trials were conducted for different varieties (Krishnaswami *et al*., 1970b; Krishnaswami, 1978, 1990; Benchamin and Nagaraj,1987). Leaves were harvested during cooler hours of the day and preserved in wet gunny cloth till the feeding time. Larvae were fed three times daily (7am, 2pm, 10pm) with healthy, fresh mulberry leaves. Young age larvae were fed with tender, succulent, nutritious leaves which are known to favour the growth and development of chawki

silkworms, while mature and coarse leaves were fed to larvae when they grow till ripening. Cocoons (Fig.3) were collected on 5th day of mounting and were assessed for commercial parameters viz., ERR, cocoon weight, shell weight, shell weight percentage, filament length, reelability percentage, denier and renditta. Methods described by Sonwalkar (1991) were employed for the assessment of cocoon quality.

Statistical Analysis.

Data collected on various parameters were tabulated and subjected to critical statistical analysis by adopting 'Method of Analysis of Variance' appropriate to the design of the experiment (Sundar raj *et al*., 1972; Singh and Choudhary, 1979).

RESULTS

Silkworm Moulting Test.

Present study showed that, highly significant differences were observed in larval weight and moulting ratio in silkworm larvae fed with selected mulberry varieties (Table-1). Silkworms reared on S_{1708} mulberry variety leaves revealed highest single larval weight (5.05mg) and moulting ratio (79.16%) and lowest single larval weight (2.74mg) and moulting ratio (66.04%) was observed in *Morus nigra* leaves during I moult. During II moult, single larval weight (25.05mg) and moulting ratio (83.26%) was found high in silkworms reared on S_{1708} mulberry variety and lowest single larval weight (15.94mg) and moulting ratio (70.04%) was recorded in *Morus nigra* leaves.

Silkworm Rearing Test.

Ten 5th instar larval weights (43.21g) was found to be significantly higher in silkworms reared on S_{1708} mulberry variety leaves and lower larval weight (34.24g) was recorded in silkworms reared on *Morus nigra*. Single cocoon weight (2.15g) was higher in cocoons obtained from silkworms reared on S_{1708} leaves whereas lower cocoon weight (1.40g) was recorded in silkworms reared on *Morus nigra* leaves. Shell weight (0.64g) and shell weight percentage (20.66%) were found significantly high in cocoons obtained from silkworms reared on S_{1708} and cocoons obtained by rearing silkworms on *Morus nigra* recorded significantly lower values in shell weight (0.23g) and shell percentage (15.12%). Filament length (1142.69mts) and reelability percentage (95%) was significantly higher in cocoons obtained by rearing silkworms on S_{1708} leaves. Significantly lower filament length (726.24mts) and lower reelability (75.10%) was recorded in cocoons harvested from rearing silkworms on *Morus nigra*. Renditta (5.07) was lower in cocoons from silkworm reared on S_{1708} leaves while significantly higher renditta (7.32) was found in cocoons recovered by rearing silkworms on *Morus nigra* leaves. Finer denier (2.08) was recorded in cocoons procured from silkworms reared on S_{1708} leaves and coarser denier (2.98) was recorded in cocoons procured from silkworms reared on *Morus nigra* leaves. Effective rate of rearing (79.98%) was high in silkworms reared on S_{1708} leaves and lower effective rate of rearing (63.76) was recorded in silkworms reared on *Morus nigra* leaves (Table-2).

DISCUSSION

Growth and development of silkworm *Bombyx mori* L. is known to vary depending on the quality and quantity of mulberry leaf used as food source, which in turn indicated by commercial characteristics of cocoon crop (Das and Sikdar, 1970; Krishnaswami *et al*., 1970a; Opender Koul *et al*., 1979; Tayade and Jawale, 1984; Thangamani and Vivekanandan,1984;

Bari *et al*., 1989; Govindan *et al*., 1987). Several reports are available on the evaluation of mulberry varieties through silkworm rearing performances (Narayanan *et al*., 1966; Iwanari and Ohno, 1969; Verma and Kushwaha 1970; Venugopala Pillai and Jolly, 1985; Das and Vijayaraghavan, 1990). It is quite evident that tender, succulent and nutritious leaves are known to favour the good growth and development of young age silkworms whereas progressively mature leaves with less moisture content are required for late age silkworms (Krishnaswami *et al*., 1970a;1971; Krishnaswami, 1990). Degree and uniformity of moulting varies with mulberry leaf quality that favours the higher moulting ratio, ensures better growth rate and silkworm larval weight (Benchamin and Anantha Raman, 1990). Chaluvachari and Bongale (1994; 1996) reported that S_{41} variety with higher protein and lower sugar content encouraged higher larval weight and lower moulting ratio. Bongale and Chaluvachari (1995) opined that, lower larval weight and moulting ratio in Mysore local variety were associated with lower leaf moisture content and moisture retention ability. Mishra *et al*., (1996) recorded 89.16% and 92.82% moulting ratio in PM x NB_4D_2 and NB_{18} x NB_7 races respectively with S_{54} mulberry genotype leaves. Sujathamma *et al*., (1999) reported that, when CB and BV larvae fed on Tr_{10} and MR_2 mulberry varieties leaves have shown higher values for moulting ratio and larval weight. Mallikarjunappa *et al*., (2000) observed the superiority of S_{30}, S_{36} and Vishwa mulberry genotypes over M_5 genotype in moulting ratio and larval weight.

Krishnaswami *et al*., (1970b) observed that Berhampore variety was better than Kosen and Mandalaya with regard to effective rate of rearing and cocoon weight. Verma and Kushwaha (1970) reported that, mulberry variety Catteneo was found best in silkworm rearing trials compared to $Burmose_2$, Tsukasakhu and Local mulberry varieties. Sengupta *et al*., (1972) observed that S_1 showed distinct varietal effect on all economic characters. Venugopala Pillai *et al*., (1987) reported that mulberry variety S_{54} encouraged higher values in larval span, larval weight, single cocoon weight and coon yield. Govindan *et al*., (1987) observed that the cocoon weight obtained with S_{41} and S_{54} was higher than that obtained with S_{36} while Mysore local and $Kanva_2$ registered the lowest. Bhemanna (1988) and Tayade *et al*., (1988) reported that mulberry variety S_{54} was found to be superior followed S_{41} and $Kanva_2$ for feeding silkworms. Dar *et al*., (1988) observed that the feeding of Ichinose leaves resulted in higher cocoon characters compared to other two varieties. Fotadar *et al*., (1989) observed that silkworm larvae fed with $Kokuso_{27}$ variety leaves revealed best results among other varieties studied. Sathyanarayana Raju *et al*., (1990) stated that the mulberry variety S_{30} showed better performance than S_{36}, S_{41} and K_2 for commercial characters of bivoltine cocoons. Saratchandra *et al*., (1992) revealed that, mulberry variety S_{36} was found superior in silkworm rearing trials and recorded highest cocoon yield, ERR and shell percentage. Changalarayappa and Chinnaswamy (1999), Vage and Ashoka (1999) reported that, silkworm breeds (PM x NB_4D_2) and (NB_4D_2) performed well when both the races larvae reared on M_5 mulberry variety leaves. Rachotaiah *et al*., (2000) noticed that, mulberry variety RFS_{175} was found superior in silkworm reeling trials with maximum cocoon production. Rahman *et al*., (1999), Chakrovorty and Borgohain (2000), Srivastava *et al*., (2001) and Santosha Gowda V. Patil (2002) were reported that, mulberry variety S_{1635} was found superior in silkworm rearing trials with good commercial characters of cocoons when compared to all other varieties examined. Sujathamma *et al*., (2001) observed that, mulberry varieties Tr_{10} and MR_2 were found superior as they secured maximum scores for silkworm races CB(PMxNB_4D_2) and BV(NB_4D_2) in rearing tests. According to Fonseca *et al*.,(1990), Giridhar *et al*., (1990), Adolkar *et al*., (2007) and Seidavi (2011) rearing performance of silkworm races differed significantly when they are subjected to same conditions, some of them

performed better and poor performance by some races. Present study also confirms the same as S_{1708} mulberry variety gives better results in pre-cocoon and post-cocoon characters when compared to other varieties tested. Gangawar (2010) reported that, among eight mulberry varieties i.e. S_1, S_{146}, S_{1635}, AR_{12}, AR_{14}, TR_{10}, BR_2 and K_2 evaluated for nutritional potential by silkworm rearing experiments, silkworm larvae fed on BR2 variety leaves showed higher larval weight and improved economic traits like cocoon weight, shell weight and silk percentage in comparison to other varieties. Ogunleye and Johnson (2012) evaluated three silkworm races namely EC_1, EJ_1 and EJ_2 for their growth and productivity by feeding them with S_{36} mulberry leaves and reported that, EJ_2 silkworms showed a higher and consistent growth rates compared to other silkworm races for all the developmental stages. Cocoon weight and shell weight are the most important characters evaluated for productivity (Gaviria *et al*., 2006). Shell weight percentage indicates the amount of raw silk can be reeled from the given quantity of fresh cocoons and shell weight percentage varies according to age and breed of silkworm. According to FAO (1999) total silk filament length is ranging from 600m-1500m out of which only 80% is reelable. In the present study, silk filament length of cocoons recovered from silkworms reared on different mulberry varieties falls within this range and cocoons recovered from silkworms reared on S_{1708} mulberry variety leaves produced longest filaments length and lowest denier.

CONCLUSION

Moulting and rearing performance of bivoltine silkworms proved to be better when fed with S_{1708} mulberry variety leaves. Commercial cocoon characters were recorded well in cocoons procured from silkworms reared on S_{1708} leaves. Next to S_{1708} mulberry variety, triploid varieties viz., Tr_8, Tr_{12} and Tr_{20} were proved promising. Leaves of these varieties supported good growth and development of silkworm larvae, which is reflected in better commercial cocoon characteristic features. Mulberry varieties M_5 (check), MS_5 and *Matigara black* occupied last place in bioassay results. From the results, it is reported that, mulberry variety S_{1708} turns out to be superior in silkworm rearing tests compared to other varieties examined under same agro climatic conditions. Such mulberry variety can be recommended for more trials at field level by farmers and could be exploited for commercial purpose in Kolar district of Karnataka state for sustainable growth and development of sericulture industry.

RECOMMENDATION

Earlier during 1980s mulberry varieties like S_{36}, S_{41}, S_{46}, S_{54} etc., were tested and evolved and during late 1990s mulberry varieties like S_1, S_{146}, S_{1635}, AR_{12}, AR_{14}, TR_{10}, BR_2 etc., were evaluated for nutritional potential. In recent years more new mulberry varieties like Tr_8, Tr_{12}, Tr_{20}, S_{1708}, MS_5, *Matigara black*, C_6, C_{10}, *Morus nigra* were evolved through breeding and were screened to know the nutritional quality of the leaves of these varieties. Mulberry being the sole food of silkworm *Bombyx mori* L. the nutritional quality of leaves was evaluated through bio-assay using moulting test which is a standard recommended practice all over the sericulture countries. The results thus obtained from these new mulberry varieties is presented in this paper which is self-explanatory. This additional information generated will help the breeder as well as the silkworm rearers to use new mulberry varieties for higher yield, healthy silkworms and good commercial parameters of silkworm cocoons.

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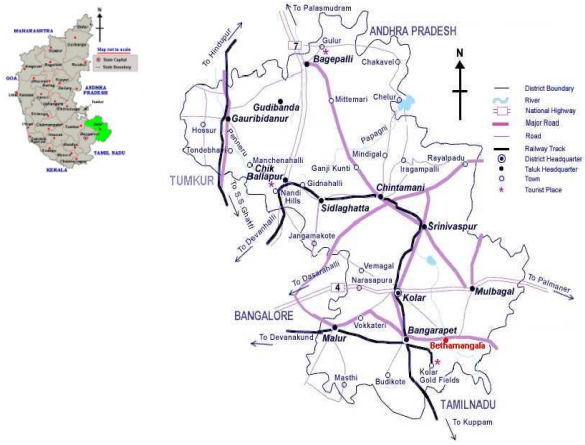

Fig.1: Map showing location of study area: **Bethamangala** in Kolar District

Fig.2: 5th instar bivoltine (NB_4D_2) silkworm larvae.

Fig.3: Bivoltine (NB_4D_2) cocoons.

Table 1: Moulting test parameters of bivoltine (NB_4D_2) silkworm larvae reared on different mulberry varieties

Mulberry varieties	I Moult		II Moult	
	Single larva weight (mg)	Moulting ratio (%)	Single larva weight (mg)	Moulting ratio (%)
S_{1708}	5.05	79.16	25.05	83.26
Tr_8	4.10	77.76	24.21	81.32
Tr_{12}	3.97	76.43	23.31	80.29
Tr_{20}	3.80	74.68	22.42	78.45
MS_5	3.65	74.41	21.83	78.34
C_{10}	3.50	73.40	21.28	77.61
M_5	3.32	72.14	20.85	76.20
Matigara black	3.08	70.03	20.25	75.80
C_6	2.99	67.82	17.17	71.44
Morus nigra	2.74	66.04	15.94	70.04
CD @ 5%	0.02	0.03	0.03	0.02

Table 2: Rearing performance of bivoltine (NB_4D_2) silkworm larvae reared on different mulberry varieties.

Mulberry varieties	Weight of 10 5^{th} instar larvae(g)	Single cocoon weight (g)	Single shell weight (g)	Shell weight percentage (%)	Filament length (mts)	Reelability percentage (%)	Renditta	Denier	ERR (%)
S_{1708}	43.21	2.15	0.64	20.96	1142.69	95.00	5.07	2.08	79.98
Tr_8	42.29	1.97	0.39	19.78	1092.80	88.89	5.87	2.21	78.08
Tr_{12}	41.22	1.79	0.36	19.40	1011.63	88.15	6.10	2.43	77.58
Tr_{20}	40.68	1.74	0.34	18.53	964.46	87.50	6.17	2.58	69.53
MS_5	39.33	1.72	0.32	18.15	948.90	86.00	6.20	2.62	76.07
C_{10}	38.03	1.70	0.31	17.98	940.04	82.63	6.29	2.69	75.10
M_5	37.54	1.69	0.30	17.75	909.19	80.60	6.42	2.74	68.25
Matigara black	36.61	1.59	0.28	16.87	836.86	78.63	6.70	2.82	67.82
C_6	35.12	1.48	0.25	15.96	786.26	76.65	7.02	2.91	65.84
Morus nigra	34.24	1.40	0.23	15.12	726.24	75.10	7.32	2.98	63.76
CD @ 5%	0.03	0.01	0.01	0.14	29.04	7.23	0.02	0.04	0.43